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Rocks are Human Beings: Researching the Humanizing Metaphor in Earth Science Scientific Texts

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Georgina Cuadrado[α] & Pilar Durán[σ]

Abstract- This paper describes a corpus-based analysis of the humanizing metaphor <<ROCKS ARE HUMAN BEINGS>> and supports that constitutive metaphor in science and technology may be highly metaphorical and active. The study, grounded in Lakoff's Theory of Metaphor and in Langacker's relational networks, consists of two phases: firstly, Earth Science metaphorical terms were extracted from databases and dictionaries and, then, contextualized by means of the "Wordsmith" tool in a digitalized corpus created to establish their productivity. Secondly, the terms were classified to disclose the main conceptual metaphors underlying them; then, the mappings and the relational networks of the metaphor <<ROCKS ARE HUMAN BEINGS>> were described. Results confirm the systematicity and productivity of the metaphor in this field, show evidence that metaphoricity of scientific terms is gradable, and support that Earth Science metaphors are not only created in terms of their concrete salient properties and attributes, but also on abstract human anthropocentric projections.

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I. Introduction

Linguistics has undergone a cognitive shift giving a greater emphasis on meaning and on the conceptual structures underlying language. This paradigm has affected the study of the conceptual system of science and technology, where Cognitive Theory and the Contemporary Theory of Metaphor (CTM) are now generally accepted to be essential to the analysis of concept formation and development. However, further empirical support is still needed, especially within scientific and technical contexts.

Recent research in metaphor use within different fields of science and technology points to the fact that specific knowledge is organized by means of metaphorical conceptualization: Cuadrado and Durán, 2013, in science and technology; Roldán & Ubeda, 2013, in Civil Engineering; Robisco, 2011, in Aeronautics; Cuadrado, 2010, in Mechanical Engineering; White 2004, White and Herrera 2009, in Economy; Cuadrado and Berge, 2003 in Physics, to mention a few. However, no previous work has been found concerning the gradability of metaphorical scientific and technical terms other than Cuadrado and Duran's recent publication (2013), which needs to be further developed. Regarding metaphor gradability in general language several studies are found (Müller, 2008; Svanlud, 2007; Hanks, 2006); yet, these studies are not concerned with scientific technical language.

Accordingly, this paper presents an analysis of the semantic structure of metaphors that contribute to conceptualize the world of Earth Science, based on the Conceptual Theory of Metaphor (Lakoff & Johnson, 1980, 1999; Lakoff, 1987, 1993) and on Langacker's notion of models of relational networks (1987, 1990). The semantic study of this metaphor relates to a larger research project of metaphorical terms in science and technology concerned with topics such as conceptual structure, category organization, and knowledge representation[1]. The humanizing metaphor of rocks has been selected due to the large number of metaphorical terms and mappings found, and its relevance in order to illustrate the systematicity and productivity of metaphors.

The first aim of the study is to determine the metaphors underlying the conceptualization of the entity 'rocks', and establish the systematicity and productivity of the mappings in this complex well-structured conceptual metaphor, very frequently found in the fields of geology, environmental science, mineralogy, geophysics, and other related fields. For this purpose, corpus-based analysis was used. Then, the models activated by the metaphorical terms found were established.

The second aim of the study is to apply the notion of metaphorical gradability to Earth Science terms, and to confirm that scientific metaphors can be highly metaphorical. When applied to metaphor, gradability refers to the degree of metaphoricity a metaphor has, thus implying that some metaphors are more metaphorical than others. According to the Prototype theory, concepts are defined in terms of their properties. This gives rise to the notions of centrality and metaphorical gradability, by which some concepts are more central than others. Thus, according to Hanks

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(2006), the fewer semantic properties the source domain and the target domain share, the more metaphorical a metaphor is, and vice versa. However, Hank's study is concerned with metaphor as a figure of speech. "His findings are based on BNC and provides good, clear examples''. from general language such as 'a storm of..', 'a sea of..', 'an oasis of..'. On the other hand, Müller's (2008) and Svanlud's (2007) studies are concerned with the different dimensions of conventionality and do not include the idea of centrality, nor analyse scientific terminology.

We propose that the parameters to measure metaphoricity in science and technology may be based on an objectivist description of the concepts, and on the distance between the real objective world and the metaphor (Cuadrado & Durán, 2013), rather than on linguistic factors such as conventionality, the salient meaning of a word, or other pragmatic aspects. Although we consider that Hank's (2006) proposal, based on the semantic attributes of words can also be applied to metaphorical terms in science and technology, we argue that another important aspect to be taken into account when approaching metaphorical gradability is that of centrality. Both approaches are complementary rather than competing, and add on to the argument that some metaphors are more metaphorical than others. Thus, the present work will show that terminological metaphors created from central models of the relational networks of a concept are less metaphorical than those derived from non-central models. The term 'mother rock' will be presented as a case study to illustrate this thesis.

Whereas high metaphoricity has long been expected to occur in literature, this has not been the case when referring to abstract, scientific concepts. The assumption that scientific terms can be highly metaphorical contradicts the widespread belief that, -to be consistent with the ideal of clear, simple, accurate and unambiguous scientific and technical communication-, metaphorical terms have to be justified in terms of logical motivation or of their explanatory power. It also contradicts scientists' belief that good scientific metaphors must derive from the source and target domains essential attributes, and, accordingly, the more semantic properties the source domain and the target domain share, the better a scientific metaphor is (Cuadrado, 2005).

Moreover, Schmitt (2005) proposed three criteria for the identification of metaphor so as to avoid subjective intuitions, which comprise the understanding that (i) a word in a given context may carry a meaning different from its literal meaning; (ii) the literal meaning comes from an area of physical or cultural experience (the source area); (iii) this meaning is transferred to a another, often abstract, target area. This proposal unveils his view of the use of a concrete source domain to explain abstract concepts. More recently, Roldán and Ubeda (2013: 109), when dealing with metaphor in the civil engineering context, state that "In metaphor, abstract concepts are understood in terms of concrete, physical ones. In other words, physical concepts act as a source domain for abstract concepts in the target domain". This paper questions such generalised belief and focuses on data showing that the source domain (human experience in our case) is frequently quite more abstract than the target domain (rocks' scientific terms), at least in Earth Science fields.

II. Methodology and Description of the Corpus

The methodology adopted, which starts with the analysis of metaphorical terms to unfold the cognitive mappings underlying language, involves the study of meaning in context; hence, corpus-based analysis was used. The unfolding of such metaphors involved these stages:

a) Hand searching of metaphorical terms in specialized dictionaries.
b) Definition and decomposition of the terms into their semantic components.
c) Contextualization of lexicalized constitutive metaphors using the electronic corpus of specialized written texts created for this purpose; examples were provided to illustrate the metaphorical terms. This corpus constitutes the third main source of scientific and technical metaphorical entries.
d) Analysis and classification of the metaphorical terms included in the database to establish conceptual metaphors and mappings.

a) Hand searching of metaphorical terms in specialized dictionaries

Our first task was to determine which dictionaries to use for the hand searching phase. After consultation with some professors from the area, we selected some updated specialized dictionaries, containing a substantial number of entries, which covered all the areas under study. These are the most representative:

- *Dictionary of Geology*. Dorothy Farris Lapidus. Collins London and Glasgow. 1987.
- *Dictionary of Mining Terms*. Paul W. Thrush and the Staff of the Bureau of Mines. Maclean Hunter. 1990.
- *Glossary of Geology*. Neuendorf, K., Mehl, J., Jackson, J.A. (eds). American Geological Institute (4th Edition), 2000.
- *Oxford Dictionary of Earth Sciences*. (1991/ 2003/ 2008), web linked Earth Science terms and definitions, with 6,250 entries.
- *Oxford Dictionary of Environment and Conservation* (2007), with over 8000 entries with coverage of economic, geographical, and political terms.

- *McGraw-Hill Dictionary of Scientific and Technical Terms* (2000), with some 110,000 terms and 125.000 definitions of 104 specific fields.

The search was completed with Electronic dictionaries on the web, mostly corpus-based.

In looking for metaphorical terms, the method in which researchers examine terms and decide what is metaphorical is perhaps the commonest approach to identification (Low, 1999: 49). However, Low adds that, in identifying metaphorical terms, there is a problem related to familiarity with specific words and that the researcher's knowledge of the topic area being studied may be considered a variable in metaphor identification. To avoid this handicap, we consulted with professors specialised in the areas dealt with whenever we had a doubt; this was possible because of our status as linguists and faculty members of the Agronomy and Mining Engineering Schools at UPM.

Therefore, the following common criteria constituted the basis for our decisions:

1. Determine the literal meaning (or meanings) of the word in non-scientific language.
2. Determine the specific meaning in the area of Earth science.
3. Contrast the specific scientific meaning and the basic meaning of the term in general language, and
4. Decide whether the scientific meaning provides more information than the basic meaning, and whether the term cannot be completely understood if only the general meaning is applied.

Based on these selection criteria, an initial list of metaphorical terms was elaborated. All the terms selected constitute technical or sub-technical vocabulary, i.e. they appear systematically in the specialised language studied.

b) Definition and decomposition of the terms into their semantic components.

At this stage, both the specific scientific definitions of the terms and their semantic components were analysed. During the process, we found out that definitions themselves constituted an important source of further lexicalized metaphors.

In our database we incorporated many words that are metaphoric in their origins because we observed that in science and technology, as in general language, in most of the cases of lexicalized metaphors, metaphorical mappings are still active and generate a series of new metaphors, both lexicalized and non-lexicalized.

c) Contextualization of lexicalized metaphors by means of a specific corpus

A specific untagged corpus of on-line scientific and technical reviews, created for the larger METACITEC[1] project, was used. Only this time, we limited the corpus to the subject areas under study, to about two million words from the period 1999-2007. We considered this size appropriate for our purposes, as "not only [specialised corpora] are likely to contain fewer words in all, but it seems as if the characteristic vocabulary of the special area is prominently featured in the frequency lists, and therefore a much smaller corpus will be needed for typical studies than is needed for a general view of the language" (Wynne, 2004:18).

Contextualization of lexicalized metaphors by means of a digitalized corpus offers a discourse approach to terminological analysis. Besides, corpora also favour the identification of those semi-technical lexicalized metaphors which are usually generated by other metaphors in real communication, with the advantage of finding those semi-technical terms as well as other frequent common vocabulary in science and technology, which may not be recorded in most specialised dictionaries.

The list of periodicals from which the research articles were taken appears in the reference section. The selection criteria of the texts is summarised in table 1.

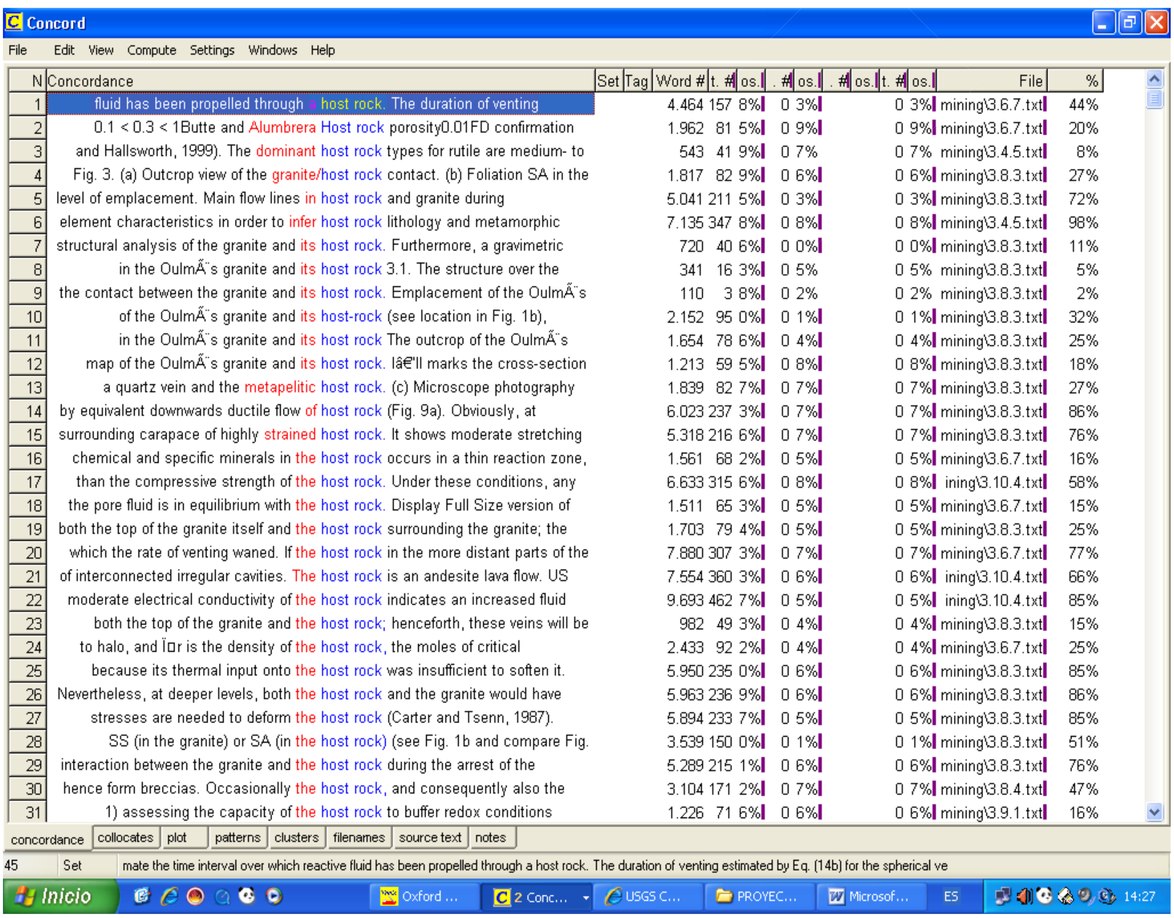
Table1: Text selection criteria

Mode of text	electronic (on line and web published paper periodicals)
Type of text	scientific articles; research papers; popular science
Domain	academic; professional
Subject areas	engineering geology, petrology, geochemistry, geography, tectonics, seismology, vulcanology, mineralogy, and geophysics.
Language varieties	American English; British English
Date	From year 2000 onwards

At this stage, all the metaphoric scientific and technical terms found in a visual inspection of specific dictionaries were studied with the Wordsmith programme. The use of a digitalized corpus provides two different dimensions to linguistics research. The horizontal one showed the information concerned to the particular text in a linear string; this dimension revealed the power of metaphorical terms to generate new metaphors, as well as the related metaphors belonging to the same domains. The vertical dimension made it possible to compare and observe the differences and regularities among the 23 lines which were shown at once in every particular screen.

Once we had contextualized a word by means of that software, and to avoid a possible over-interpretation of the data as metaphors when they were not, we read and analysed each expanded concordance lines found. By way of an example, we bring the metaphorical compound term 'host rock' (fig 1). We found out that it appeared in 45 different cases (frequency). Obviously, the collocation of the word *host* followed by *rock* meant that the former was always metaphorical, since host defines a person who receives guests, and there was no possible over-interpretation of the term as a metaphor. However, a possible case of over-interpretation could have taken place in line number 3, where *dominant* was found preceding the compound 'host rock'. But, as it was part of the word group 'dominant host rock type', the word was discarded to be considered metaphorical.

Although the information concerning word frequency is not of primary importance for this particular study, the analysis of the association of words and lexical constellations provides substantial information about the potential of metaphor to generate new metaphors and new meaning; this serves as a cognitive model in scientific language and thought. In our analysis we looked for the selected words within a span of five places to the right and five places to the left of the node word (search term), looking for new possible metaphors generated by the metaphorical term itself. Thus, in line 4, we found the metaphorical terms from plants 'outcrop' and 'foliation'; in lines 13 and 23 the anatomical terms 'quartz vein', 'veins', etc. So, the development of an electronic corpus as a source of empirical data has allowed us to establish different conceptual mappings underlying this field of scientific thought other than the humanizing ones.



N	Concordance	Set	Tag	Word #	t. #	os.	. #	os.	. #	os.	t. #	os.	File	%
1	fluid has been propelled through a host rock. The duration of venting			4.464	157	8%	0	3%			0	3%	mining\3.6.7.txt	44%
2	0.1 < 0.3 < 1Butte and Alumbrera Host rock porosity0.01FD confirmation			1.962	81	5%	0	9%			0	9%	mining\3.6.7.txt	20%
3	and Hallsworth, 1999). The dominant host rock types for rutile are medium- to			543	41	9%	0	7%			0	7%	mining\3.4.5.txt	8%
4	Fig. 3. (a) Outcrop view of the granite/host rock contact. (b) Foliation SA in the			1.817	82	9%	0	6%			0	6%	mining\3.8.3.txt	27%
5	level of emplacement. Main flow lines in host rock and granite during			5.041	211	5%	0	3%			0	3%	mining\3.8.3.txt	72%
6	element characteristics in order to infer host rock lithology and metamorphic			7.135	347	8%	0	8%			0	8%	mining\3.4.5.txt	98%
7	structural analysis of the granite and its host rock. Furthermore, a gravimetric			720	40	6%	0	0%			0	0%	mining\3.8.3.txt	11%
8	in the OulmÃ¨s granite and its host rock 3.1. The structure over the			341	16	3%	0	5%			0	5%	mining\3.8.3.txt	5%
9	the contact between the granite and its host rock. Emplacement of the OulmÃ¨s			110	3	8%	0	2%			0	2%	mining\3.8.3.txt	2%
10	of the OulmÃ¨s granite and its host-rock (see location in Fig. 1b),			2.152	95	0%	0	1%			0	1%	mining\3.8.3.txt	32%
11	in the OulmÃ¨s granite and its host rock The outcrop of the OulmÃ¨s			1.654	78	6%	0	4%			0	4%	mining\3.8.3.txt	25%
12	map of the OulmÃ¨s granite and its host rock. lâ€'ll marks the cross-section			1.213	59	5%	0	8%			0	8%	mining\3.8.3.txt	18%
13	a quartz vein and the metapelitic host rock. (c) Microscope photography			1.839	82	7%	0	7%			0	7%	mining\3.8.3.txt	27%
14	by equivalent downwards ductile flow of host rock (Fig. 9a). Obviously, at			6.023	237	3%	0	7%			0	7%	mining\3.8.3.txt	86%
15	surrounding carapace of highly strained host rock. It shows moderate stretching			5.318	216	6%	0	7%			0	7%	mining\3.8.3.txt	76%
16	chemical and specific minerals in the host rock occurs in a thin reaction zone,			1.561	68	2%	0	5%			0	5%	mining\3.6.7.txt	16%
17	than the compressive strength of the host rock. Under these conditions, any			6.633	315	6%	0	8%			0	8%	ining\3.10.4.txt	58%
18	the pore fluid is in equilibrium with the host rock. Display Full Size version of			1.511	65	3%	0	5%			0	5%	mining\3.6.7.txt	15%
19	both the top of the granite itself and the host rock surrounding the granite; the			1.703	79	4%	0	5%			0	5%	mining\3.8.3.txt	25%
20	which the rate of venting waned. If the host rock in the more distant parts of the			7.880	307	3%	0	7%			0	7%	mining\3.6.7.txt	77%
21	of interconnected irregular cavities. The host rock is an andesite lava flow. US			7.554	360	3%	0	6%			0	6%	ining\3.10.4.txt	66%
22	moderate electrical conductivity of the host rock indicates an increased fluid			9.693	462	7%	0	5%			0	5%	ining\3.10.4.txt	85%
23	both the top of the granite and the host rock; henceforth, these veins will be			982	49	3%	0	4%			0	4%	mining\3.8.3.txt	15%
24	to halo, and Ï□r is the density of the host rock, the moles of critical			2.433	92	2%	0	4%			0	4%	mining\3.6.7.txt	25%
25	because its thermal input onto the host rock was insufficient to soften it.			5.950	235	0%	0	6%			0	6%	mining\3.8.3.txt	85%
26	Nevertheless, at deeper levels, both the host rock and the granite would have			5.963	236	9%	0	6%			0	6%	mining\3.8.3.txt	86%
27	stresses are needed to deform the host rock (Carter and Tsenn, 1987).			5.894	233	7%	0	5%			0	5%	mining\3.8.3.txt	85%
28	SS (in the granite) or SA (in the host rock) (see Fig. 1b and compare Fig.			3.539	150	0%	0	1%			0	1%	mining\3.8.3.txt	51%
29	interaction between the granite and the host rock during the arrest of the			5.289	215	1%	0	6%			0	6%	mining\3.8.3.txt	76%
30	hence form breccias. Occasionally the host rock, and consequently also the			3.104	171	2%	0	7%			0	7%	mining\3.8.4.txt	47%
31	1) assessing the capacity of the host rock to buffer redox conditions			1.226	71	6%	0	6%			0	6%	mining\3.9.1.txt	16%

Figure 1: Fragment of Concordances of The Word "Host Rock" Found in the Digitalized Corpus of Earth Sciences.

a) Analysis and Classification of the Metaphorical Terms Found in the Corpus

In this work, we identified over 1000 Earth Science metaphorical entries, which were analysed and classified, both thematically and structurally. Metaphorical gradability was measured by means of (i) the comparison of the word definitions of both the source and the target domain, and their decomposition into their semantic components, that is, by analysing their shared properties and attributes (quantity); and (ii) by establishing which models are activated in the source and target domains, and if any of these models are more central than others (quality).

III. Results

After the analysis, we found out that over 35 terms were related to the description of rocks by means of the humanizing conceptual metaphor; since research is in progress, this number is by no means definite. The frequent presence of the humanizing metaphor shows that it is deeply embedded in the collective experience of the scientific community.

Results showed that <<ROCKS ARE HUMAN BEINGS>> activates two different sub-metaphors: (i) rocks are living organisms, encompassing the metaphors of age, the reproductive behaviour, and the family, all of which make up the genealogical model; and (ii) rocks are collective entities with social traits, which forms the social model.

a) The genealogical model

Related to the first sub-metaphor, the terms found in specialised dictionaries and contextualized in the corpus are the following: 'mature', 'immature', 'maturity', 'juvenile', 'young', 'age', 'generation', 'family', 'parent rock', 'parent material', 'mother rock', 'parental rock', 'coupling', 'daughter element', 'twin crystal', 'twin rocks', 'to twin', 'to descend', 'descendant', 'ancestor' and 'ancestral'. These terms involve the following mappings:

- <a class of minerals and rocks is a family of rocks>
- <rocks from which minerals and rocks are descended are parent rocks or mother rocks>
- <an element from which later elements are descended is a parent element>
- <an element descending from another is a daughter element>
- <an organism from which later organisms are descended is an ancestral organism>

Next, all the terms related to the genealogical model are presented, including a brief explanation of their meaning in context and showing an illustrative example taken from the digitalized corpus or the web[2].

- 'Generation': meaning a class, or set of rocks.

Example 1: "A new *generation* of zircon, characterized by very high Th/U and low U, grew at that time. That event — deformation and possibly a minor rise in temperature — produced widespread perturbations of other isotopic systems throughout the Napier Complex." (*Science Direct,* 2007: 2-20*).*

- 'Family': meaning a class of rocks. In the following example, we identified the expression "to form a family".

Example 2: "The site settles with great amount of igneous rocks, sandstone, shale and limestone as well as where the strong effects of metamorphism happened because of the movement of mountain building. Consequently, the *family* of metamorphosed complex has formed mainly consisting of black schist, green schist, siliceous schist and marble."(*ScienceDirect,* 2007: 2-20*).*

- 'Parent rock' and other related terms. They refer to the original rock from which other material was formed. The term 'parent rock' is also used in the context of metamorphic rocks where 'parent rock' refers to the original rock before metamorphism takes place. 'Parent rock' is the main source of soil. This type of soil is also called residual soil. Similar terms are 'parent body', 'parent mineral', 'parent substances', and 'parent material'; the latter meaning the underlying geological material in which soil is formed, sometimes, synonym with 'bedrock'.

Example 3: "Provenance analysis aims to reconstruct and to interpret the history of sediments from the initial erosion of *parent rocks* to the final burial of their detritus, encompassing all factors such as the geologic, physiographic and climatic context of the source area". *(Provenance of Albian sandstones in the São Luís–Grajaú Basin (northern Brazil) from evidence of Pb–Pb zircon ages, mineral chemistry of tourmaline and palaeocurrent data.)*

Example 4: 'parental rock' and 'age': "Essentially all paleosols, regardless of *age*, retain some characteristics of soils formed under an oxic atmosphere, such as increased Fe3+Ti ratios from their *parental rocks*". *(Evidence in pre–2.2 Ga paleosols for the early evolution of atmospheric oxygen and terrestrial biota, Hiroshi Ohmoto, Geology, The geological society of America)*

- 'Bedrock'. The term 'bedrock' may be considered as part of the genealogical model sub-metaphor as it refers to the native solid rock that produces loose 'parent material', such as soil, sand, clay or gravel, which make up local rocks or hold them in place.

Example 5: "The earth's crust is composed of rock. But the type of rock is different in most places. Rock which occurs at any given place on the earth is called that location's *bedrock*. In some cases the *bedrock* is actually exposed, and is said to outcrop at the surface. *Outcropping bedrock* is great stuff, because it allows geologists to determine the local geology, and helps them put together the geologic history of the earth." (http://www.jersey. uoregon. edu/~mstric/AskGeoMan)

- 'Mother rock', meaning the rock in which minerals are found implanted.

Example 6: "The type of Nannihu oversize molybdenum deposit belongs to skarn-porphyry type, which ore-forming *mother rock* is almost the same with 25 deposits in east Qinling-dabie mountain ore-forming belt." (*Environmental Science Technology,* 35: 6, 1067*).*

- 'Daughter element', meaning the element formed when a radioactive element undergoes radioactive decay.

Example 7: "The quantitative AFC model we have developed to explain isotopic variation in Ruapehu lavas is undoubtedly a simplification of the complex processes that might have actually been involved; for example, progressive contamination from the assumed

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parent to a single end-member *daughter composition* …" (*Science Direct,* 2007: 437-451).

- 'Age', meaning the ratio of the traces of the 'parent rock' and the 'daughter', expressed in years. This allows for comparison of the 'ages' of different rock strata.

Example 8: "The discovery of radioactivity enabled scientists to develop techniques for determining the *age* of fossils, rocks (…) Precise laboratory measurements of the number of remaining atoms of the *parent* and the number of atoms of the *daughter* result in a ratio that is used to compute the *age* of a fossil or rock in years. (…) one layer of rock is younger or older than another" (*Evolution and the Fossil record, pp 16-17*).

- 'Twin' and 'twin crystals': identical rock crystals are considered 'twin crystals'.

Example 9: "*Twinning* of the e-plane is the dominant crystal–plastic deformation mechanism in calcite deformed below about 400 °C. Calcite in a *twin* domain has a different crystallographic orientation from the host calcite grain. So-called thin *twins* appear as thin black lines when viewed parallel to the twin plane at 200–320× magnification under a petrographic microscope. Thick *twins* viewed in the same way have a microscopically visible width of *twinned material* between black lines." (Calcite twin morphology: a low-temperature deformation geo-thermometer, D.A. Ferrill, A.P. Morris, M.A. Evans, M. Burkhar, *Journal of Structural Geology*, Vol 26, Issue 8, August 2004, pp 1521–1529).

- 'Ancestor' and 'ancestral rock': an organism from which later organisms are descended is considered an ancestral organism.

Example 10: "Sources for a few suites having compositions indicative of recycled orogenic provenances were probably cover strata eroded off the crests of subdued basement uplifts. The sandstones were derived from highlands within the *ancestral rock* (…) (http://gsabulletin. gsapubs.org/ content/94/2/222. short)

- 'To descend' and 'descendant', meaning to derive from an earlier form.

Example 11: "Documentation of *ancestor-descendant* relationships among organisms comes from all fields. (…) The fossil record remains first and foremost among the databases that document changes in past life on Earth" (*Evolution and the Fossil record,* p 3).

b) The social model

The terms involved in the humanizing sub-metaphor <rocks are social entities> are: 'population, community, member, assemblage, native rock, host rock (developed from the peripheral features from the social domain), to host, intrusive rock, and allied rock'. 'Intrusive rock' activates the metaphor of war and is related to the terms 'intrusion, intruder, invasion, and allied'. Next, some examples in context[2] are provided.

- 'Population' meaning all the organisms that constitute a specific group or occur in a specified habitat.

Example 12: This zircon is part of a *population* of zircons within the metamorphosed conglomerate, which is believed to have been deposited about 3060 Ma, which is the age of the youngest detrital zircon in the rock. (http://en.wikipedia.org/wiki/Oldest_rock# Oldest_terrestrial_material)

- 'Community', taken as a group of interdependent organisms in the same region, which share some characteristics in common, as in the case of 'sea floor communities'.

Example 13: "Benthic, or sea floor, *communities* gave rise to the Cincinnatian Series limestone through a process called lithification. These *communities* were diverse and underwent frequent dramatic changes, which contributed to sediment formation. Such changes were often precipitated by events that wiped out most life in a given local *community*". http://www.cas.muohio. edu/glg/museum/students/conceptsingeology/benthicc ommunities.html.

- 'Member': a part of a lithostratigraphical formation is a member

Example 14: "The Alderley Edge data have been divided into two groups, one representing discontinuities in the Wilmslow Sandstone Formation (marked (W), and one representing discontinuities in the Thursaston *Member* of the Helsby Sandstone Formation (T)." *(ScienceDirect - Journal of Contaminant Hydrology:* Vol 93, Issues 1-4, 15, August 2007, pages 38-57).

- 'Mineral assemblage', meaning a gathering of minerals that form together in a rock at the same pressure and temperature at a given time

Example 15: If a rock is taken to some high pressure and temperature, then the *mineral assemblage* that develops should represent stable chemical equilibrium (*Earth Environmental Sciences. Metamorphic Mineral Assemblages, 2003).*

- 'Native rock': a mineral/element occurring in nature in its free state is a native mineral/element.

Example 16: "Modified asphalt was successfully prepared based on AH-70 bitumen with *native rock* asphalt modifier, and favorable performance was obtained. *Native rock* asphalt dramatically upgraded its high-temperature performance, improved its thermal susceptibility (…)". (*Influence of Performance of Modified Asphalt by Native Rock-Asphalt*, Fan, Shen, Journal of Building Materials, 2007)

- 'To host' and 'host rock': a 'host rock' refers to a rock which contains other rocks or mineral deposits.

Example 17: "Prior to granite *intrusion*, the *host rocks* were affected by a main deformation phase responsible for the development of a penetrative slaty cleavage and regional-scale folds. Granite emplacement

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gave way to a 2 km-thick strain aureole, which includes both the uppermost part of the stock and the surrounding *host rocks*."

- (*Journal of African Earth Sciences*, Volume 48, Issue 5, August 2007, pp 301-313).

- 'Intrusion', with a two-fold meaning: a) The forcing of molten rock into an earlier formation, and b) the rock mass produced by an intrusive process. See example 17 above.
- 'Intrusive rock': it is the rock resulting when magma cools and crystallizes slowly within the earth "crust; synonym with plutonic rock".

Example 18: "It is believed that there are some special actions to form reservoir spaces, especially the solution pores and cracks in the *intrusive rock* and its exomorphic zones, because the rock's diagenetic evolution was completed in a reduction environment". ("The lithofacies and reservoir model of *intrusive rock* and its exomorphic zones". *Petroleum Exploration and Development* 2000-02. Zhang, Ying Hong; et al. 2000, 27 (2): 22-26).

- 'Rock creep', referring to the slow and continued movement of small pieces of rock on hillsides.

Example 19: "Under the same general heading [rock-falls and rock slides] come the very slow movements of surface layers on slopes, such as soil creep and *rock creep* on hillsides, which continue over a long period and may ultimately displace trees, fences, and lines of communication". (Blyth & Freitas, 1974, *A Geology for Engineers,* p. 51).

- 'Dike swarm' referring to a large group of more or less parallel dikes.

Example 20: "The orientations of intrusive rocks from a carbonatitic lamprophyre *dike swarm* and the history of emplacement relative to country-rock schist structures are compatible with intrusion into tension fractures and Riedel shears formed during initiation of the dextral wrench system of the Alpine fault". (Cooper, Barreiro, Kimbrough, & Mattinson. *Geology*, The geological society of America).

- 'Allied rock', referring to rocks belonging to related families ranking between an order and a class.

Example 21: "There are, however, no hard and fast boundaries between *allied rocks*. By increase or decrease in the proportions of their constituent minerals they pass by every gradation into one another, the distinctive structures also of one kind of rock may often be traced gradually merging into those of another". *Journal of Petrology* 1986, 27(1): 155-196).

- 'Coupling', meaning the union of two elements that produce new substances.

Example 22: "Carbonates from subducted oceanic lithosphere may be remixed into the Earth's deep mantle via both redox "freezing" and melting that is driven by carbon and iron redox *coupling*, caused by redox capacity changes in the mantle." (*Nature,* March 2011. Rohrbach & Schmidt "Redox freezing and melting in the Earth's deep mantle resulting from carbon–iron redox *coupling*" Vol 472, pp 209-212. http://www.nature.com/natura/journal/v472/n7342.html)

c) Case study: Mother rock.

The term 'mother rock' has been brought here as an example to illustrate a highly metaphorical term which has not been created solely in terms of its salient "motherly" properties, but in terms of human imagination, as we shall demonstrate. The term shares both essential and non essential attributes with the human concept of "mother".

Thus, the word "mother" is defined primary as: "A female parent; a woman who has given birth to a child. Correlative with son or daughter" (OED, 1989, vol. IX, 1121). In figurative language, it can be used "with reference either to a metaphorical giving birth, to the protecting care exercised by a mother, or to the affectionate reverence due to a mother".

Its more prominent attributes are "female parent" and the process of "giving birth". According to the OED, by means of metaphorical extension of its properties, it activates the concepts: "protecting care" and "affectionate reverence".

-A stone or a rock is defined as "a hard mineral substance (other than metal) of a small or moderate size". Accordingly, its prominent properties are hardness and size, marked by the elements that make up the rock. By metaphorical extension of its properties it activates the attributes: motionless or fixity, stability or constancy. In figurative sense, the words 'stone' or 'rock' are applied to "chiefly as the supposed substance of a hard heart, also a hard or unfeeling person" (OED, 1989, vol. XVI 757).

Within the Earth science context, a 'mother stone' is "The matrix of a mineral; also, a stone from which other mineral are derived by structural or chemical change" (OED, 1989, vol. IX, 1123). This implies that human imagination describes the changes by which a rock derives into other minerals turning to the concept of motherhood.

At this point, cognitive linguists may want to find out which semantic properties and attributes take part in the model involved. So, in order to determine the degree of metaphoricity of this particular term, we have to establish which models are activated in the term, and if any of these models are more central than others. First of all, we observe that it activates the metaphorical model of genealogy, which in the source domain is absolutely peripheral, if not inexistent. That is, it is not central to the concept of rock. Therefore, we may deduce that the number of attributes and properties that human motherhood and 'mother rock' share in common only exist in human imagination.

As Santibanéz (2001) explains "none of the sub-models suffices to characterize the concept on its own". However, some of the sub-models characterizing a given metaphorical term are more central than others, and suggests that certain models provide the invariant for the concept (Wierzbicka 1996). For instance, 'mother rock' and 'parent rock' derive from the genealogical model, which is in fact another conceptual metaphor. Thus, it is possible to affirm that this complex system of related metaphors is not created from central models, and allows us to conclude that it is an example of high metaphoricity. Furthermore, the analysis of metaphorical terms in Earth Sciences also confirms the theory that metaphors are not created solely in terms of their salient properties, but in terms of human imagination as well, i.e. metaphors are created from both, essential and non essential attributes.

IV. Discussion

In order to illustrate the evidence that humanizing metaphors in Earth Science have a large component of human imagination, we have developed a table showing the relationships among the lexicalized metaphors involved in <<ROCKS ARE HUMAN BEINGS>> that fall under the two main models analysed, the genealogical and the social model (table 2). Under the genealogical model three other sub-models converge: the generation, birth and marital models, which coincide with Lakoff's (1987:37) analysis of the concept of mother. Lakoff's model encompasses five aspects: birth, marital, genetic (supplies genetic material), nurturance (takes care), and genealogical. In our study, the genetic and the nurturance models have not been found, and terms such as parent(al) rock, parent material, parent body, and mother rock have been classified under both the birth and the marital sub-models, as they share properties of both of them; we may add that 'parent material' could have been interpreted to fall under the genetic model.

By contrast, we have found another model, the social one, including concepts related to grouping and to individual social traits. In this case, we have also come across terms which we consider to share properties from two sub-models, the marital –under the genealogical model-, and the grouping sub-model –under the social model. These terms are: 'family' and 'coupling', first classified under the marital sub-model, but which also have a social component. Finally, terms included in the social model like 'allied rock' vs 'intrusive rock' generate a new sub-model of human behaviour based on friendship and the acceptance or rejection of a new member in the group. This is the case of Boninite, which is defined as a high-magnesian basalt dominated by pyroxene, and of 'dike' or 'dyke', which in geology is a type of sheet intrusion referring to any geologic body that cuts discordantly across.

Table 2 : lexicalized metaphor models for the conceptual metaphor <<ROCKS ARE HUMAN BEINGS>>

THE GENEALOGICAL MODEL		/	THE SOCIAL MODEL	
GENERATION M. /	BIRTH M. /	MARITAL M. /	GROUPING /	SOCIAL TRAITS
to descend	parent(al) rock	parent(al) rock	population	native rock
descendant	parent material	parent material	community	to host
ancestral rock	parent body	parent body	member	host rock
ancestor	mother rock	mother rock	assemblage	intrusive rock
age	daughter element	bedrock	dike swarm	allied rock
maturity	to twin	coupling	coupling	to intrude
mature/ immature	twin crystals	family	family	intrusion
young, juvenile	twin rocks			rock creep

The findings portrayed in section 3 seem to contradict the stance of the CTM that the source domain is less abstract, i.e. more accessible to sense perception, than the target domain. In all cases shown in table 2, as in the case study of the term 'mother rock', the concrete physical domain of rocks is conceptualized by means of more complex abstract domains, including social traits such as hostility ('intrusive rock'), hospitality ('host rock'), and friendship ('allied rock'). Moreover, these findings provide further support to maintain that part of the main content of natural science is organized by the humanizing metaphor based on human experience and projection (Cuadrado and Durán, 2013).

V. Conclusions

The humanizing metaphor of rocks, one of the most productive conceptual patterns found in our corpus analysis, shows that metaphorical lexical units are not independent one from another but constitute connected semantic networks that give support to the conceptual system of this area of science. The findings also show that lexicalised metaphorical terms are highly active, and that a great part of geological science is organized by the humanizing metaphor, given the relevance of the conceptualization of rocks in this discipline. The understanding of the natural world is based on inherent semantic relations among words which are conceptualized by means of different intertwined models and sub-models of human experience; this is the case of the genealogical and the social models applied to the analysis of the conceptual metaphor <<ROCKS ARE HUMAN BEINGS>>.

This semantic analysis contradicts some assumptions of conceptual metaphors, thus opening new research lines in the CTM. Given the importance of the conceptualization of rocks in the study of geology, this analysis provides empirical support to maintain that: (i) the trend from abstract to concrete, postulated by the CTM in general language, is not followed in Earth Science, and, therefore, contradicts the rationale proposed for general language, where abstract difficult to handle domains are often understood in terms of concrete domains. As shown in the previous analysis, the concrete, physical domain of rocks is conceptualized by means of more complex abstract domains, including human social traits such as friendship, hostility and hospitality. Results knock down the notion that (ii) metaphor in science is usually understood in terms of its explanatory or informative power, and (iii) that in science, metaphorical thought is usually based on analogical reasoning rather than on human experience and imagination.

This work also shows evidence that gradability can be applied to metaphorical terms in this field by means of the decomposition into the terms' semantic components. And, more importantly, it provides a theoretical framework to evaluate metaphoricity based on the centrality of the models of relational networks which are activated by a metaphorical term. Results offer empirical evidence that scientific metaphors are not mainly defined in terms of their salient properties and attributes but in terms of human experience.

Although many other factors must be taken into account in order to establish metaphoricity, for example, the quantity of properties, and the salient meaning of a word, this paper can open a new research line in the right direction, as it has aimed to demonstrate that, in science and technology, different metaphorical terms present different degrees of metaphoricity, some of them being highly metaphorical. The implications of these results may provide the basis for further studies on the generation and role of metaphor in constructing meaning within science and technology.

Notes

[1]METACITEC is a terminological database result of a research project financed by the regional government of Madrid (Spain) and the Universidad Politécnica de Madrid (UPM), integrated into the research and development lines (R+D) of 'Science and Society'.

[2]Contextualised terms have been highlighted in italics by the authors.

[3]The research articles contained in the corpus were extracted from the following sources: *Journal of Earthquake Engineering, Geodiversitas, Earth Moon and Planets, Chemical Geology, International Journal of Applied Earth Observation and Geoinformation, Earth and Planetary Science Letters, Soil Dynamics and Earthquake Engineering, Journal of African Earth Sciences, Journal of Contaminant Hydrology, Geothermics, The Electronic Journal of Geotechnical Engineering, Applied Clay Science, Computers and Geosciences, Sedimentary Geology.*

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